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Knowledge Networks: A Case Study in Establishing a Domain of Software Engineering Knowledge

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Abstract

One of the key tenets of work in the social studies of science and technology (ssst) is that the *conditions* of scientific and engineering knowledge determine their *contents* (Bijker et al., 1987; Bijker & Law, 1992; Woolgar, 1991; Pickering, 1992; Hacking, 1999; Latour, 1999). In other words, the content of knowledge is not a mirror of what is. Rather it is a constructed and contingent network of representations, artifacts, processes and skills that could have been otherwise if social, cultural, economic and cognitive¹ conditions were otherwise. In the context of ssst, these networks have been called actor² networks (Callon, 1986; Callon et al., 1986; Callon, 1991; Callon et al., 1997; Latour, 1987; Latour, 1991; Latour, 1996).

For the purposes of this paper, actor networks in which scientific and engineering knowledge is established, maintained and extended are referred to as knowledge networks. The aim of our work in progress is to study knowledge networking and to participate in a potential, emerging software engineering knowledge network. One outcome of the work will be to produce a case study of the potential software technology transition network we are helping to establish. Additionally, we plan to evaluate and adopt new methodologies and tools that support the development and study of knowledge networks.

Introduction

In part, our work is concerned with theoretical notions of networks—socio-technical networks, actor networks, knowledge networks and the like. In part, it is also concerned with how a small but well situated group participates in the establishment and development of a knowledge network, as it establishes the conditions for its

future work on technology change management³ within the larger domain of software engineering. This group, which is currently called the Accelerating Software Technology Adoption (ASTA) group, is now in the process of re-defining its R&D focus. ASTA's current goals are to:

- advance the body of knowledge for maturing and introducing software innovations.
- provide key and practical information so that organizations can routinely achieve the benefits they expect when acquiring or introducing software innovations.
- encourage and support collaborations of technology developers, acquirers, users and maintainers to introduce innovations and to improve ways of discovering and moving that knowledge into practice.
- shorten the time between innovation and effective practice

Our (authors'/researchers') view of knowledge creation and knowledge networks is different from ASTA's inherited perspective on software engineering knowledge. However, we, the authors/researchers, are part of ASTA. The inherited perspective is largely derived from the process movement within software engineering. We hope that a knowledge network perspective will restore interest in social and cognitive factors necessary for successful technology transition.⁴ Since the researchers are members of ASTA, this counter play on what constitutes knowledge may become a meta-theme of the current study. However, our primary goal is to characterize and chart the life of a particular knowledge network—its current status and potential growth—and to determine research and development methods that offer visibility into its workings and provide for its effective support.

¹ What is meant by "cognitive" here is not so much a matter of formulating hypotheses and testing them but getting the equipment in a laboratory or technology at work to cooperate.

² In actor network theory, the term "actor" is not limited to human actors. Almost any object or process, whether animate or inanimate can be an actor.

³ The group has recognized that this domain is broad, encompassing technology forecasting, development, application, adoption, insertion, deployment, and diffusion.

⁴ The ways the knowledge network perspective may supplement the inherited process perspective is discussed briefly in the next sections.

Networks, networks, everywhere

Socio-technical networks refer to the interactions among people, groups, texts and technologies in intricate heterogeneous arrangements. Actor networks have emphasized that in such networks what is "social" and what is "technical" cannot be readily isolated. In this sense, technologies (sometimes in the form of mechanisms or processes) can play an active role in the creation and maintenance of networks. Agency is not only distributed, it is distributed amongst people, texts, artifacts and processes.

The development, adoption and use of software technology, especially technologies supporting information systems like the Internet, Intranets and collaborative virtual workspaces can be understood in terms of the dynamics of actor networks. An actor network can become a software engineering knowledge network if it supports the articulation and codification of information flowing through a network while also continuing to support the development, adoption and use of software technology.

Perhaps what is most striking here is not the subtle distinctions—between socio-technical networks, actor networks, and knowledge networks—but common conditions compelling us to create terminology that describes the new ways we communicate and work. Use of information technology and infrastructure invented by software engineering offers a challenge to rethink the concept of agency and patterns of activity, for human and non-human agents alike, for networking and information sharing. The network metaphor, especially in the form of actor networks, supports this new way of thinking about agency with respect to knowledge creation.

Why are knowledge networks significant?

Why should one care about knowledge networks? We believe that the concept of knowledge networks enlarges our understanding of activity in design disciplines. Studies (Forman & Sanchez-Ron, 1996) have shown that hard sciences often side step the social and cognitive factors associated with the creation of domain knowledge. While the field of software engineering has taken steps toward addressing these issues as a science of the artificial,⁵ it often covers up the social and cognitive conditions that certain of its approaches and concepts were introduced to uncover. Perhaps nowhere is this better seen than in the process movement, within the software engineering domain, where process has

progressively been stripped of many of its cognitive and social contingencies. Not all disciplines omit consideration of these contingencies. For reasons we do not entirely understand but are exploring, the related disciplines of information technology and information systems have created a larger intellectual space where technical and social issues are given their due and recognized as having mutual impact (Brown & Duguid, 2000).

The concept of knowledge networks obliges us to consider the conditions required to produce knowledge, including the means of knowledge production, infrastructure, processes, goods and technical objects. Our tendencies to think about technology either as (1) completely under our control, as a kind of social determinism, or (2) completely controlling, as technological determinism, are both dislodged. Actor networks enable recognition of numerous distributed social and technological factors, no one of which is *a-priori* privileged. Knowledge networks extend these considerations to focus on information, concepts, processes, procedures and methods important in solving problems *across* various kinds of local boundaries, e.g., communities of practice, organizations, institutions, nations, languages and cultures. Extensions are made possible by alliances and other types of relationships with firms, research and technical centers, government agencies and users across these boundaries. A range of intermediary elements (Callon et al., 1997) can then strengthen or weaken these relationships, e.g.,

- written documents (scientific articles, reports, patents, etc.)
- embodied knowledge (researchers, engineers, technical staff and managers moving from one institution or organization to another),
- technical objects in varying stages of development (hardware and software, tools and end-products, prototypes and deliverables)
- money (collaborative contracts between a research center and a firm, grants, loans, purchases)
- informal exchanges, processes, procedures, methods and techniques.

Only against the background of collectives or social configurations does the data, information, interpretation, categorization and validation needed for knowledge begin to make sense. Networks offer a vehicle to understand these configurations. This is critical in technology change management activities, involving adaptation to changing relationships among researchers, developers, suppliers and users.

In Search of a Method

The authors are participant action researchers (Whyte, 1991) in the study. We are participating in ASTA activities, in establishing conditions for a new focus in

⁵ Herb Simon's conception of the sciences of the artificial acknowledges the cognitive conditions underlying knowledge production in the design sciences, e.g., the engineering sciences, software engineering, information technology and systems, and management sciences. However, we believe, he falls short in accounting for the social and political forces at work in these contexts.

technology change management and studying the role of ASTA in the relevant contexts to see how this can be achieved. All of ASTA is not necessarily in agreement about the role of knowledge networks in technology change management, in ASTA's activities, and in the current study. Only the researchers have this express interest on all three fronts.

Part of our research aims, in good actor network fashion (Latour, 1987; Callon, 1991), to convince ASTA to see its work as knowledge networking. The study will employ the same collaborative technology that ASTA is using to capture and organize information. In this sense, our approach borrows from interpretive case study methodology (Braa & Vidgen, 1997; Walsham 1993 cited in Braa & Vidgen). We seek to elaborate actor network theory by articulating the concept of knowledge network based on a concrete case – the work of ASTA. We will attempt to extrapolate from the detailed description of our particular case to consider patterns in emerging knowledge networks.

Our perspective combines elements of participatory action research with a case study approach since we anticipate some intervention on our part and also strive to describe what we observe. Our approach to studying knowledge networks will be continually evaluated and refined. Reactions from ASTA to describing the results of their work as an instantiation of knowledge networking will be recorded as part of the ongoing evaluation. The authors and ASTA members are reflective practitioners (Schön, 1983; Schön, 1995) who will also take a reflexive position in questioning the research framework as an integral part of the research (Woolgar and Ashmore, 1988; Woolgar, 1988).

Related research has focussed on actor networks (Callon, 1986; Callon et al., 1986; Callon, 1991; Callon et al., 1997; Latour, 1987; Latour, 1991; Latour, 1996; Latour, 1999), communication networks (Krackhardt, 1990; Krackhardt, 1992) citation analysis (Small, 1973; Ellis et al., 1999) and co-word analysis (Callon et al., 1986; Callon et al., 1991; Coulter et al., 1998). While these perspectives are valuable, they all are based on limited access to pertinent information. For example, research inspired by actor network and communication network theories depends on information collected after the fact by researchers who are dependent on documentation and informants they can identify. Citation analysis and co-word analysis usually rely on published technical literature, providing useful information on research in important areas of transition, but offering no answers on actual cases of how work is carried out in these areas. In part, the challenge of the present inquiry is to explore approaches and methods that shine light on the dynamics of knowledge networks *in vivo*—how they come into existence and change through time.

Subjects

ASTA is part of a federally funded research and development organization created to support the transition of software engineering knowledge into practice. Part of the responsibility of this organization is to identify and/or establish software-engineering bodies of knowledge and know-how for the software engineering community, especially the Department of Defense (DoD) who provides ASTA's core funding. ASTA is beginning to make contact with the TCM community. This community/configuration, which may or may not be a knowledge network, is distributed over a number of agents, including:

- groups and organizations in the DoD and outside, developing and adopting software technologies and software-intensive systems
- people with embodied organizational, technological and change management knowledge
- capacities of these groups, including key players, to communicate via social and technical infrastructure
- software technologies and software-intensive systems.

Research Focus: Links and Connections

A key goal for this study is to specify, with descriptions of concrete cases, what constitutes a link between agents and how such links are connected in a network. Clearly, mutual awareness and communication are important. In the case of knowledge networks, recurring topics and themes, as parts of a body of knowledge are also relevant. In addition, commonality and connectivity give us insight into branching of specialized areas where a small subset of participants may be acknowledged as leading experts. Professional and institutional mechanisms support commonality and acknowledgement of expertise across groups and organizations. These mechanisms typically include scientific or professional societies, standards groups, governmental and public financial support, forms of certification, training and established curricula. While institutional support is important to the growth and maintenance of knowledge networks, our focus is on the initial stages in the formation of a knowledge network—where the ground is prepared. What kinds of relationships among groups and artifacts must be in place for a knowledge network to emerge? We assume that one mark of knowledge is its ability to be transmitted intact across local boundaries. What infrastructures and agreements must be established? What kinds of boundaries need to be crossed? Goals, situations and problems must be collectively described and designated. Our aim is to begin to operationalize these concepts according to the relationships that ASTA members construct in their knowledge networking efforts.

A large part of our effort will be to identify key factors and conditions in establishing a knowledge network for software technology change management. We are also interested in the interaction of these factors, in what hinders or prevents interaction and how a domain of practice may become a domain of knowledge over time.

Understanding how a knowledge network is formed involves understanding how data and information are communicated and captured as a basis for knowledge. Do narratives or stories play a role (for example, the role of war stories, lessons learned, etc... – see Brown and Duguid, 1991)? Are differences in terminology and meaning reconciled, and if so, how? Under what conditions, is knowledge from research applied and transformed into knowledge for practice? Is knowledge from practice fed back into research?

Collaborative Tools and Processes for Performing Work and Capturing Data

ASTA has already established means for intra-group communication through face-to-face meetings, email and use of collaborative work tools. ASTA has also started to identify and contact external candidates who might participate in creating a network. All information collected about these candidates, their organizations and their views on technology change management, will be stored and organized in the collaborative work technology being used. The collection of tools currently employed is called BSCW (Basic Support of Cooperative Workspace).⁶ BSCW is being used to:

- store, annotate, organize and share meeting notes, important email, plans, evolving documents and descriptions of the ASTA's tasks and outcomes
- identify and provide links to potential contacts and sources of information about success and failure in software technology change management; categorize and store summaries of their contents
- coordinate information about contacts, questionnaires and interviews; rate the potential contribution of the contacts for establishing a knowledge network.

The information sharing enabled by BSCW across time and at a distance⁷ will provide traces of the knowledge network that may or may not be emerging, flourishing or declining. For these traces to be useful in indicating salient features of these networks, careful attention must be paid to the partitioning and re-partitioning, categorizing and re-categorizing, linking and re-linking of folders and sub-folders, and discussions emerging in the BSCW workspace. In other words, the

impact of new information added to the workspace carries the potential for a re-design of its information architecture.⁸ We hypothesize that the information architecture will become the knowledge representation of the knowledge network. A collaborative tool that supports the social construction of a knowledge network also supports its knowledge representation (Monarch et al., 1997).

To provide a sense of how BSCW can be used to give shape to knowledge representations and networks, we attach and briefly describe several screens of the contents of ASTA's BSCW workspace. The first screen (Screen 1 – located after the References below) shows the organization of ASTA Team 1's work. Two of the folders represent the major work of the team – collecting information on software technology transition and change management and identifying and contacting key players in this area. The other two folders contain information on the task plan for the team and extensive notes from meetings. Note that the time stamps provide a history of when each of these activities began. Screen 2 shows the areas of technology change and transition being investigated; Screen 3 shows a further breakdown of one of these areas, military technology transition and change management. Screen 3 shows the tree-like classification structure that begins to serve as a representation of ASTA's work.

The representation is not simply tree-like; there are also lateral links between branches at various levels of the BSCW workspace. For example, in Screen 2, there is a link to ASTA's library of documents and other supplementary information located in a different branch of the information tree. Moreover, the links in the sub-folder, Navy Tech Transition, are to Navy web sites that are themselves representations of the work the Navy is doing in this area. There are similar links for other services and parts of the DoD as well as non-military government and public agencies, and industry and universities both national and international. ASTA's workspace is becoming the stage for a representation⁹ of a potential knowledge network of those interested in software technology transition.

One desired outcome of ASTA's research is, therefore, the production of an annotated web-based map of the software technology change management and technology transition network. Through this work, the researchers hope to describe and demonstrate how the concepts of actor and knowledge networks provide a

⁶ BSCW is a product of the GMD in Germany.

⁷ The phrase "at a distance" refers to BSCW's capability of providing an online information-sharing environment for people who are traveling, in different offices or in different organizations.

⁸ One is reminded here of the memory theatres that Francis Yates beautifully describes in her book *The Art of Memory* (1984). However Renaissance memory theatres were not able to reconfigure themselves as readily as the information architectures being described here.

⁹ There are software tools available to draw maps of such WWW networks.

useful lens for interpreting and understanding the network being represented. An important part of this effort will involve convincing ASTA of the viability and value of understanding their work in terms of these concepts.

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ASTA Group Workspaces in BSCW

Screen 1



Screen 2



DoD & Services' Tech Transition & Change Management - Netscape

File Edit View Go Communicator Help

ira / ASTA / ASTA Business Case Development / Teams / Team 1: Customer Perspective & Requirements / Information Being Collected

DoD & Services' Tech Transition & Change Management

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